The Rise of the Proton Structure Function $\boldsymbol{F_2}$ Towards Low $\boldsymbol{x}$ *

Jörg Gayler, DESY

on behalf of the H1 collaboration

Results on the derivative of $\log(F_2)$ with respect to $\log(x)$ at fixed Q^2 are presented. The measured derivatives are within errors independent of x for $Q^2 \geqq 0.85$ GeV^2 and increase linearly with $\log(Q^2)$ for $10^{-4} \leqq x \leqq 0.01$ and $Q^2 \gtrapprox 3$ GeV^2. The results are based on preliminary and published H1 data which at Q^2 below 2 GeV^2 are combined with NMC and ZEUS data.

1. Introduction

The rise of the proton structure function F_2 towards small Bjorken x has been discussed since the existence of QCD. In the double asymptotic limit (large energies, i.e. small x, and large photon virtualities Q^2) the DGLAP evolution equations [1] can be solved [2] and F_2 is expected to rise approximately like a power of x towards low x. A power like behaviour is also expected in the BFKL approach [3]. However, it soon was discussed [4] that this rise may eventually be limited by gluon self interactions in the nucleon, or more generally due to unitarity constraints.

Experimentally this rise towards small x was first observed in 1993 in the HERA data [5]. Meanwhile the precision of the F_2 data is much improved and the rise can be studied in great detail.

2. Procedure

The low x behaviour of F_2 at fixed Q^2 is studied locally by the measurement of the derivative $\lambda \equiv -(\partial \ln F_2/\partial \ln x)_{Q^2}$ as function of x and Q^2. The results are based on preliminary H1 F_2 data presented to this conference [6] covering the range $0.5 < Q^2 < 3.5$ GeV^2 and published H1 data [7], [8] which cover the range $1.5 < Q^2 < 150$ GeV^2. The low Q^2 F_2 data were obtained by shifting the ep interaction vertex by 70 cm in proton beam direction [6]. At $Q^2 < 2$ GeV^2 the H1 data are also shown combined with

* Presented at DIS2002, Kraków, 30.4. - 4.5. 2002

data of NMC [9] and ZEUS [10]. The derivative $\lambda(x, Q^2)$ is evaluated using data points at adjacent values of x at fixed Q^2 taking into account error correlations and x spacing corrections. The derivatives are compared with the next to leading order (NLO) QCD fit to the H1 cross section data [7] and a “fractal” fit [11] where self-similar properties of the proton structure are assumed.

3. Results

The x and Q^2 dependence of $\lambda = -(\partial \ln F_2/\partial \ln x)_{Q^2}$ is shown in Fig. 1.

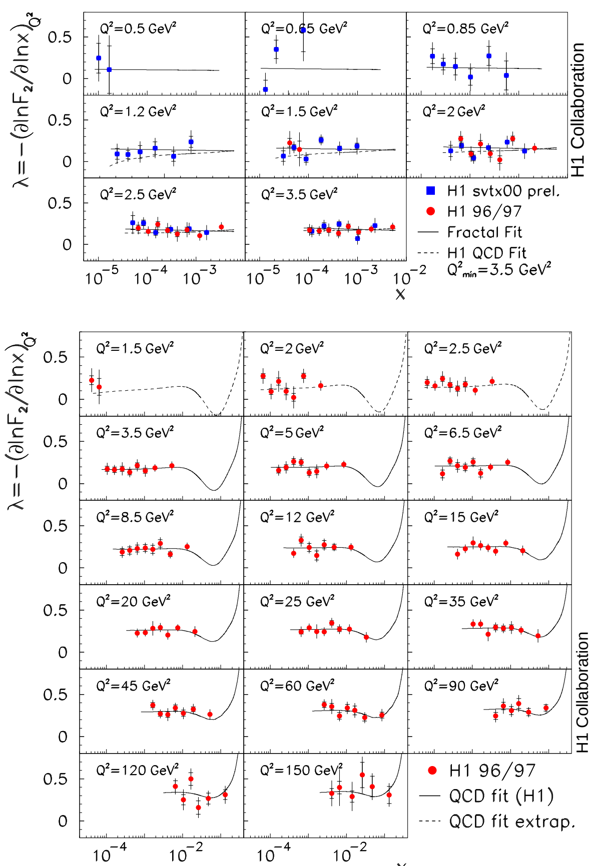

Fig. 1. Derivative $\lambda = -(\partial \ln F_2/\partial \ln x)_{Q^2}$ compared with the QCD analysis of ref. [7] and a “fractal” fit [11] for $0.5 < Q^2 < 3.5$ GeV^2 (upper plot) and for $1.5 < Q^2 < 150$ GeV^2 (lower plot)

The new shifted vertex and the published data agree well in the overlap region. The derivative λ is constant within experimental uncertainties for fixed Q^2 in the range $x < 0.01$, implying that the data are consistent with the power behaviour $F_2 = c(Q^2) \cdot x^{-\lambda(Q^2)}$. Fitting this form for each Q^2 bin to the data at $x < 0.01$, results in the λ and c values presented in Fig. 2.

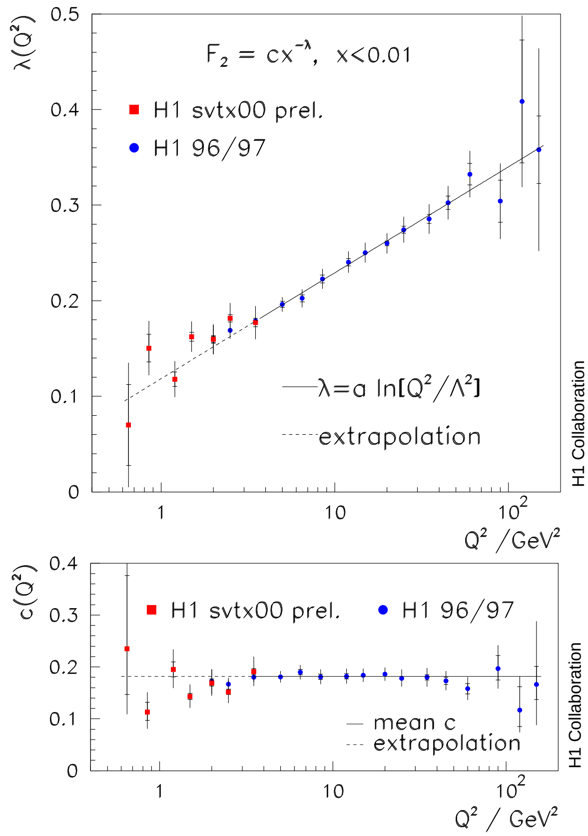

Fig. 2. $\lambda(Q^2)$ and $c(Q^2)$ from fits of the form $F_2 = c(Q^2) \cdot x^{-\lambda(Q^2)}$ to the H1 structure function data [7] and [11].

The results show that the F_2 data at low x for $Q^2 \gtrapprox 3.5$ GeV^2 can be well described by the very simple parameterisation

$$F_2 = c \cdot x^{-\lambda(Q^2)} \ , \ \text{ with } \ \lambda(Q^2) = a \cdot \ln[Q^2/\Lambda^2] \tag{1}$$

with $a = 0.0481 \pm .0013 \pm .0037$ and $\Lambda = 292 \pm 20 \pm 51$ MeV and $c \approx 0.18$.

At low Q^2 the deviation of λ from the logarithmic Q^2 dependence and the decrease of $c(Q^2)$ is more significant if the H1 data are combined with

NMC [9] and ZEUS [10] data (see Fig. 3).

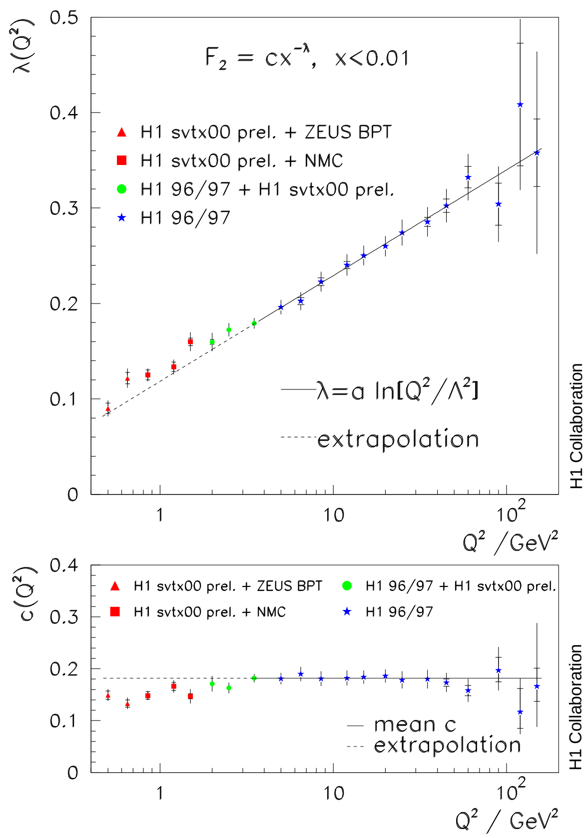

Fig. 3. $\lambda(Q^2)$ and $c(Q^2)$ from fits of the form $F_2 = c(Q^2) \cdot x^{-\lambda(Q^2)}$ combining the H1 structure function data of [7] and [11] and the H1 data with data of NMC [9] and ZEUS [10].

The deviations from a simple constant respectively logarithmic behaviour occur at about such Q^2 values below which perturbative QCD fits (e.g. [7]) are not supposed to be valid. At small Q^2 the structure function F_2 can be related to the total virtual photon absorption cross section by

$$\sigma_{tot}^{\gamma^* p} = 4\pi\alpha^2 F_2/Q^2 \ \sim x^{-\lambda}/Q^2 \tag{2}$$

where the total $\gamma^* p$ energy squared is given by $s = Q^2/x$. For $Q^2 \to 0$ we can expect $c(Q^2) \to 0$ and $\lambda(Q^2) \to\approx 0.08$. The latter value corresponds to the energy dependence of soft hadronic interactions $\sigma_{tot} \sim s^{\alpha_{I\!P}(0)-1}$ with $\alpha_{I\!P}(0) - 1 \approx 0.08$ [12] which is approximately reached at $Q^2 = 0.5$ GeV^2.

4. Conclusion

No significant deviation from the power behaviour $F_2 \sim x^{-\lambda}$ at fixed Q^2 is visible at present energies and $Q^2 \gtrsim 0.85$ GeV^2. More specifically:

- For $x < 0.01$ the derivative $\lambda \equiv -(\partial \ln F_2/\partial \ln x)_{Q^2}$ is independent of x within errors.
- λ is proportional to $\ln(Q^2)$ for $Q^2 \gtrsim 3$ GeV^2, i.e. in the pQCD region.
- Here the data can be very simply parametrised by $F_2 = cx^{-\lambda(Q^2)}$.
- At $Q^2 \lesssim 3$ GeV^2 deviations from the logarithmic Q^2 dependence of λ are observed.
- At low Q^2 ($Q^2 \lesssim 1$ GeV^2) the energy rise is similar as in soft hadronic interactions.

REFERENCES

[1] Y. L. Dokshitzer, (In Russian)," Sov. Phys. JETP **46** (1977) 641 [Zh. Eksp. Teor. Fiz. **73** (1977) 1216];
V. N. Gribov and L. N. Lipatov, Yad. Fiz. **15** (1972) 1218 [Sov. J. Nucl. Phys. **15** (1972) 675]; Yad. Fiz. **15** (1972) 781 [Sov. J. Nucl. Phys. **15** (1972) 438];
G. Altarelli and G. Parisi, Nucl. Phys. B **126** (1977) 298.

[2] A. De Rujula et al, Phys. Rev. D **10** (1974) 1649;
R. D. Ball and S. Forte, Phys. Lett. B **335** (1994) 77.

[3] E. A. Kuraev, L. N. Lipatov and V. S. Fadin, Sov. Phys. JETP **44** (1976) 443 [Zh. Eksp. Teor. Fiz. **71** (1976) 840]; Sov. Phys. JETP **45** (1977) 199 [Zh. Eksp. Teor. Fiz. **72** (1977) 377];
I. I. Balitsky and L. N. Lipatov, Sov. J. Nucl. Phys. **28** (1978) 822 [Yad. Fiz. **28** (1978) 1597].

[4] L. V. Gribov, E. M. Levin and M. G. Ryskin, Nucl. Phys. B **188** (1981) 555; Phys. Rept. **100** (1983) 1;
A. H. Mueller and J. w. Qiu, Nucl. Phys. B **268** (1986) 427.

[5] I. Abt *et al.* [H1 Collaboration], Nucl. Phys. B **407** (1993) 515;
M. Derrick *et al.* [ZEUS Collaboration], Phys. Lett. B **316** (1993) 412.

[6] T. Lastovicka, these proceedings.

[7] C. Adloff *et al.* [H1 Collaboration], Eur. Phys. J. C **21** (2001) 33.

[8] C. Adloff *et al.* [H1 Collaboration], Phys. Lett. B **520** (2001) 183.

[9] M. Arneodo *et al.* [New Muon Collaboration.], Phys. Lett. B **364** (1995) 107; Nucl. Phys. B **483** (1997) 3.

[10] J. Breitweg *et al.* [ZEUS Collaboration], Phys. Lett. B **487** (2000) 53.

[11] T. Lastovicka, arXiv:hep-ph/0203260 and these proceedings.

[12] A. Donnachie and P. V. Landshoff, Phys. Lett. B **296** (1992) 227.